

CHAPTER 7

HIGH ALTITUDE ELECTROMAGNETIC PULSE (HEMP) AND HIGH POWER MICROWAVE (HPM) EQUIPMENT AND CONTROLS

7-1 General HEMP protection systems

Command, control, communications, computer, intelligence, surveillance, and reconnaissance (C4ISR) facilities contain miniature solid-state electronics. These devices will fail when subjected to voltages that exceed the dielectric strength of the component or when the device melts as a result of heating from currents induced by a radio frequency (RF) pulse. Most people are familiar with the effects of lightning upon solid-state equipment. Other sources are high power microwave (HPM), ultra wide band (UWB) waveforms, and high altitude electromagnetic (EM) pulse (HEMP). A nuclear weapon detonated 300 km above the United States can blanket the entire continental United States with the HEMP effects.

7-2 HEMP protection systems

Traditional methods of electromagnetic interference (EMI) isolation often use metal enclosures to prevent unwanted radiation from entering the circuit. These shields provide effective protection along with good grounding techniques; therefore, HEMP protection systems are static as they do not have any moving parts. An exception to this is finger stock material that springs into place when doors or windows are closed. Only during an electromagnetic pulse (EMP) environment does the system function to shield the hardened facility. HEMP protection system components should not be disturbed or disconnected. The following should be inspected/tested to verify that installation is correct and magnetic pulses will not cause damage to the mission or render it inoperative.

a. Electronic surge arresters. An area in which care must be taken to ensure compatibility in EM integration is surge protection. Some surge arresters used for lightning do not clamp fast enough to protect against HEMP. Some used for HEMP may not have great enough current carrying capacity for lightning protection in all situations. Check for bonding, shielding, and grounding.

b. Shielding. For HEMP-hardened facilities, some kind of EM shielding is essential. Shielding involves the use of a barrier or series of barriers to reduce the magnitude of the EM energy incident upon the electronic or electrical system to be protected. Shielding philosophy can be developed around different approaches. Check for bonding, shielding, and grounding.

(1) Global shielding (or hardening) is a protection concept that uses an overall shield to encompass the entire facility. In this approach, all conducting penetrations and all apertures are protected at the shield. The intent is to keep all HEMP fields and HEMP-induced transients outside the protected volume. The global shield could be placed on the entire outer walls, ceiling, and floor (surface) of the facility, or it could be reduced to a smaller volume that contains all

sensitive equipment to be protected. The most common shield material for global shielding of ground-based facilities is sheet steel with welded seams, although other designs can provide adequate global HEMP shielding.

(2) Tailored shielding is a protection concept in which shielding is designed and constructed according to specific protection requirements for the equipment involved. After defining the system to be protected, its possible operating configurations, the expected HEMP environment, coupling paths, equipment sensitivities, and subsystem/system criticalities, the required protection levels for various subsystems or groups of subsystems can be defined. Tradeoff studies may be performed for comparing various shielding arrangements to verify that they meet safety margins in protection, cost-effectiveness, maintainability, survivability, flexibility, and other requirements. The objective is to optimize protection for the specific mission-critical system. Tailored shielding options may include global shielding, zonal shielding, shielding of cabinets or components, or combinations thereof. In a typical tailored protection design, discrete protection will be provided to eliminate specific, localized deficiencies.

(3) Zonal or topological shielding is a concept in which a facility is divided into zones, with shielding barriers located topologically in a shield within a shield configuration. The outer zone is designated zone zero; zone one is inside shield one but outside shield two. Zones and shields are assigned increasingly larger numbers as they progress toward the more deeply nested areas.

(4) The term “system configuration” identifies which way the cables, wires, equipment, and subsystems are laid out in relationship to each other, as well as the relationship of these items to the topological boundaries. In some instances, the cables, connectors, and equipment casings are actually part of the topological protection. System configuration as defined does not directly attenuate the environment, but it is an important element in the topological protection concept. The system configuration influences protection design requirements since some configurations are easier to protect than others (e.g., co-location of all mission-critical equipment). Thus, the system configuration should be coordinated with the protection design and the protection topology will be optimal for a specific configuration. During the facility life cycle, the protection design may be required to accommodate some changes in configuration. To ensure that the configuration’s design modifications do not compromise or defeat the protection, careful configuration management is necessary. The topology should be designed to tolerate configuration changes that are totally within a boundary. The boundary can never be violated (for example, opened), only extended. All modifications must be subjected to review by HEMP experts to ensure continual compliance with the HEMP hardening requirements. Check for bonding, shielding, and grounding.

(5) Conductive or metallic cable shielding or conduit is used in the zonal/topological protection concept to extend the boundary formed by equipment enclosures and thus provide a way to interconnect elements while maintaining boundary continuity. Cable shielding is also used to protect a wire or wires as they travel from one boundary to another. This would be the case with a shielded RF signal traveling from its entrance into a building to the RF receiver. From a HEMP standpoint, the shielding attenuates coupling of radiated energy within the first boundary as the signal travels to the receiver. Of course the shield is somewhat reciprocal in that it also prevents signals from radiating out of the cable. The main feature of cable shielding is continuity of the boundary provided by the cable shield/connector combination that may require special joints.

(a) Another way to maintain this continuity and provide cable shielding is by using steel conduit to house all wires and cables. The steel conduit will provide substantially higher shielding levels than the cable shields. Check for continuous welds of pipe to shielding

(b) Both cable shields and conduit connected to a shielded zone must have equal or greater shielding effectiveness than the shield.

c. *Grounding.* The grounding system for a HEMP protected facility shall use an equipotential ground and is connected to a welded stud that does not penetrate the shield. Another stud welded to the opposite side of the shield then will be connected to the exterior grounding system.

d. *Shield penetration protection.* All shielded zones will require penetrations to allow entry of equipment, personnel, electric power, communications, control signals, ventilation, water, fuel, and various fluids. Without protection, these penetrations compromise the shield.

(1) Large access doors are often necessary to provide an entry for equipment, supplies, or vehicles into HEMP hardened facilities. In facilities that require blast overpressure protection, large blast doors are used. These doors generally use one or more thick steel plates to provide protection. The door's inherent shielding ability is thus high, but its large size presents a difficult gasketing problem. If blast protection is not required, it is still necessary to design the door with a high degree of structural strength. This step is to ensure that the door can provide the necessary gasket compression force and that proper mechanical alignment of closure contact surfaces is maintained.

(2) Two concepts are commonly used for personnel entrances: conventional HEMP/radio frequency interference (RFI) shielded doors and personnel tunnels that act as waveguides below cutoff. The shielded doors generally use metal fingerstock or EMI/RFI gaskets to provide an EM seal around the door jamb periphery. Currently available gasket and fingerstock doors require regularly scheduled maintenance and/or replacement to maintain required shielding levels. The gaskets are relatively easily damaged and also require replacement. Air-expandable doors may also be used, although they typically have more maintenance problems. These doors generally use a movable subassembly of two shielding plates on a framework that is moved on rollers in and out of a steel-framed opening. When closed, air expansion tubes cause the two shielding plates to make uniform surface contact with the frame inner surfaces.

e. *Electrical penetrations.* A common feature for electrical penetrations in a global protection approach is a cable entry vault to prevent large currents on external conductors from being conducted into the facility. Ideally, all penetrations should enter a single vault. In some cases, however, it may be necessary to separate the vault into two compartments or to use two vaults for penetrations by different types of lines: power, signal and control, and antenna. The vault must be connected directly to the external facility ground system. Conductive penetrations, such as a conduit, waveguide, or shielded cable, must have a circumferential weld or other means of providing good electrical connection at the intersection with the entry vault. The cable entry vault serves three purposes:

(1) To insure that penetrating conductors do not cause conducted HEMP energy to enter the protected topology.

(2) To contain and divert penetrator-conducted HEMP energy to the boundary exterior.

(3) To contain or divert radiant EM energy resulting from the activation of transient suppression devices subjected to a conducted pulse.

f. Transient suppression devices and filters. Transient suppression devices fill a critical gap in the concept of topological protection. The necessity to supply power to a facility and to communicate over cables or antennas are two major factors contributing to their use. Power lines entering a facility are typically connected to an unshielded power grid so that large, conducted currents must be bled off to prevent their entry into a facility. These currents are diverted to the exterior boundary of the topology. This boundary can be an overall external shield or an enclosed entrance vault. Antennas, such as for high-frequency (HF) communications, are designed to gather EM signals (at wavelengths in the HEMP frequency spectrum). Then they apply these signals to the center conductor of a shielded cable. The HEMP transients associated with an HF antenna can be, by far, the largest single signal entering a facility. Transient suppressors often are used in conjunction with filters. Filters are frequency-selective whereas surge suppressors are amplitude-selective. Filters often are used to attenuate transients associated with the non-linear operation of surge arresters. They also are used for selectively passing (or stopping) frequency bands as in the case of antenna cable penetrations. Transient suppressors are an integral part of the EM topology, demanding specific installation techniques as will be seen later. A spark gap is a surge suppressor that provides a conducting path to ground when the voltage across the device exceeds the gap breakdown level. Spark gaps with a high current capacity do not operate quickly enough to block all HEMP energy transients entering the vault. For this reason, it may be necessary to use other protection devices in conjunction with the spark gap.

g. Electromagnetic isolation. The EM isolation concept involves the use of elements either immune to interaction with EM radiation or which provide a current path interruption. Optical fibers are examples of elements immune to EM radiation that can be used to reduce the number of conductive penetrations. For practical purposes, optical fibers can be used for long communications links without signal interference from HEMP. Further, they can be used to enter shielded zones through waveguide below cutoff penetrations without compromising the EM shielding effectiveness.

h. Dielectric isolation. Other isolation techniques include using dielectric isolators for shield penetration when external metallic EM energy collectors are involved. Examples are control rods or cables (normally metallic), piping systems for fluids, and metallic duct systems for air. Dielectric sections are installed at or near the shield to prevent the energy induced on the external metallic part from being conducted through the shield. Dielectric control rods can enter through a shield in the same way as optical fibers, that is, through a waveguide-below-cutoff section.

i. Isolation switching. Although not recommended now, isolation switching has been provided at facilities so they can use commercial electric power during routine operation, but can switch to internal generators or power systems in the event of an emergency such as nuclear attack. Since the commercial power wiring is a source of significant HEMP energy injection through a shield, switching to internally generated power is an obvious advantage when advance warning of impending nuclear attack is received and throughout the entire nuclear attack cycle. This concept applies to communications lines and control lines as well as power lines. Switching used in past facility designs has been called “alert attack” switching. Such switching must provide adequate switch contact separation to prevent arcing, and must be designed to reduce coupling interactions between wiring and switch contacts to acceptable levels.